Eugene E. Lundquist

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BEARING TESTS OF 14S SHEET AND PLATE

By R. L. Moore

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SUMMARY

Tests were made to determine bearing yield and ultimate strengths of bare and Alclad 14S-W[1] and 14S-T[1] sheet and plate in thicknesses of 0.064 inch, 0.250 inch, and 0.750 inch. From the results of these tests it was concluded that the ratios of bearing to tensile properties for the with-grain direction were essentially the same as proposed in NACA TN Nos. 901, 920, 974, and 981 for other high-strength aluminum-alloy sheet and plate.

INTRODUCTION

Previous investigations of bearing strength made in the Aluminum Research Laboratories in connection with the design of riveted, bolted, or pin-connected joints have covered most of the aluminum alloys used in sheet or plate form in aircraft structural design (references 1 to 4). Although bearing-strength data have been given in reference 5 for 14S sheet, the only tests of this alloy appear to be those made on 1/4-inch-thick forged bars and reported in reference 1. In view of the importance being attached to 14S as a high-strength, general-purpose, aluminum alloy, some additional investigation of bearing properties was believed to be warranted.

The object of these tests was to determine bearing yield and ultimate strengths of several thicknesses of 14S-W and 14S-T sheet and plate and to establish approximate ratios of bearing to tensile properties.

MATERIAL

Table I gives essential data on the tempers, thicknesses, and tensile properties of the materials used for these bearing tests. It will be noted that both yield and ultimate strengths, as well as elongation values, were consistently higher for the with-grain than for the cross-grain direction. The greatest differences were observed for the yield strengths of the W temper and ranged, as shown in table II, from 10 to 20 percent. It should also be noted from table II that the cross-grain tensile properties were in every case slightly higher than

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[1]New Alcoa temper designations: 14S-W now 14S-T3 in case of 0.064-in. sheet; 14S-T4 in case of 0.250- and 0.750-in. plate. 14S-T now 14S-T6 in all cases.

published as typical for these alloys and tempers in reference 6. The maximum differences were about 10 percent. From these comparisons it was concluded that the material selected for this investigation of bearing strengths was typical of commercial 14S sheet and plate.

PROCEDURE

All the bearing tests were made on 2-inch-wide specimens cut in duplicate from both the with- and cross-grain directions. Those from the $\frac{3}{4}$-inch-thick plate were machined to a thickness of 0.250 inch from the center, whereas the specimens from the 0.064-inch and 0.250-inch Alclad samples were tested in full thickness. The 0.064-inch-thick specimens were loaded in bearing on a $\frac{1}{4}$-inch-diameter steel pin; those of 0.250-inch thickness were loaded on a $\frac{1}{2}$-inch-diameter steel pin.

Edge distances, measured in the direction of stressing from the center of the hole to the edge of the specimen, were limited in these tests to 1.5 and 2 times the pin diameter since these distances are the only ones for which bearing design values are commonly given (reference 5)

Figure 1 shows the general arrangement for making bearing tests in a 40,000-pound-capacity Amsler hydraulic testing machine. Hole elongations, from which values of bearing yield strength were determined, were obtained by measuring the relative movement of the pin and the specimen by means of a filar micrometer microscope which could be read directly to 0.01 millimeter. The projecting portion of the pin on the microscope side was flattened slightly on the under side to provide a shoulder on which the reference mark for pin movement was located. A small scratch on the specimen under the pin provided a reference mark for specimen movement.

RESULTS AND DISCUSSION

Table III gives values of bearing yield and ultimate strength and types of failure for all the bearing tests. The yield-strength values indicated were selected from the bearing stress-hole elongation curves shown in figures 2 to 7 as the stresses corresponding to an offset of 2 percent of the pin diameter.

The general behavior of the 14S specimens in bearing was the same as previously observed for the other high-strength, wrought-aluminum alloys tested in the form of sheet and plate. Failures occurred either by shearing out the portion of the specimen above the pin or by a combination of shear and tensile fracture through the pin hole. Shear failures predominated in the 0.064-inch-thick specimens, for which the ratio of specimen width to pin diameter was 8, whereas combined shear and tensile failures were obtained in the majority of the 0.250-inch-thick specimens, for which the ratio of width to pin diameter was 4. It should be emphasized, however, that these differences in specimen proportions were not in a range where they had any significant effect on the bearing properties determined.

Previous tests have indicated no marked difference in with- and cross-grain bearing properties and the values shown in table III are in generally good agreement with this observation. The maximum difference indicated in table II was only about 7 percent and the average differences for all tests under any one set of conditions did not exceed 4 percent.

Table IV gives the ratios obtained between average bearing and tensile strengths. It is quite evident from these data and those given in table V that the 14S sheet and plate samples exhibited about the same bearing-strength characteristics as previously observed for other high-strength aluminum alloys in the same form. The following nominal ratios of bearing to tensile properties, which were proposed on the basis of previous tests (references 1 to 4), appear applicable, therefore, to alloy 14S.

Ratios for with-grain tests	Edge distances	
	1.5 × pin diam.	2 × pin diam.
Bearing ultimate / Tensile ultimate	1.5	1.9
Bearing yield / Tensile yield	1.4	1.6

In three cases in table IV the with-grain ratios of bearing to tensile strengths for different thicknesses of 14S-T were as much as 8 percent less than the foregoing nominal ratios. Since these differences occurred in isolated cases, however, involving different properties or edge distances, they were not considered as significant as if uniformly low ratios had been observed for all tests of any one thickness or temper. In all other cases in table IV the deficiencies in bearing-to-tensile strength ratios for the 14S samples, when they did exist, were less than 6 percent. It should be pointed out that table V shows only two other with-grain ratios (one for 0.250-inch- and one for 2.00-inch-thick 24S-T plate) that are more than 5 percent less than the nominal ratios proposed for sheet and plate.

Emphasis has been placed thus far upon ratios of with-grain bearing to tensile properties because many of the earlier tests of sheet were limited to this direction. The only real need for differentiation with respect to direction occurs in the case of materials exhibiting a marked difference in tensile yield strength in the with- and cross-grain directions, resulting from a stretcher-levelling or flattening operation. Since bearing properties show no marked directional characteristics, the same ratios of bearing to tensile properties are not applicable to with- or cross-grain tensile yield strengths. The present practice of listing with-grain tensile properties in reference 5 greatly simplifies the use of with-grain ratios in obtaining bearing strengths. It is of interest to point out in this connection that the ratios of cross-grain bearing to tensile yield strength proposed in reference 4 for 24S-T plate reduce to approximately the same ratios as listed herein for the with-grain direction, if the cross-grain values are multiplied by the ratio of the typical cross-grain to with-grain tensile yield strength.

The allowable bearing yield stresses listed in reference 5 for 14S-W sheet are somewhat lower, in proportion to the tensile yield strength, than given for 14S-T sheet. This difference is just opposite to that observed in these tests for which the yield ratios were consistently higher for the 14S-W. The most important observation perhaps is that in only two cases do the design stresses in reference 5 correspond to a higher ratio of bearing to tensile strength than obtained in these tests and that the maximum difference for these cases was only about 7 percent.

CONCLUSION

It was concluded from tests of bare and Alclad 14S-W and 14S-T sheet and plate, in thicknesses of 0.064 inch, 0.250 inch, and 0.750 inch, that the ratios of bearing to tensile properties for the with-grain direction were essentially the same as previously proposed in NACA TN Nos. 901, 920, 974, and 981 for other high-strength, aluminum-alloy sheet and plate, namely:

Ratios for with-grain tests	Edge distances	
	1.5 × pin diam.	2 × pin diam.
$\frac{\text{Bearing ultimate}}{\text{Tensile ultimate}}$	1.5	1.9
$\frac{\text{Bearing yield}}{\text{Tensile yield}}$	1.4	1.6

Aluminum Research Laboratories
Aluminum Company of America
New Kensington, Pa., January 20, 1947

REFERENCES

1. Moore, R. L., and Wescoat, C.: Bearing Strengths of Some Wrought-Aluminum Alloys. NACA TN No. 901, 1943.

2. Moore, R. L., and Wescoat, C.: Bearing Strengths of Bare and Alclad XA75S-T and 24S-T81 Aluminum Alloy Sheet. NACA TN No. 920, 1943.

3. Wescoat, C., and Moore, R. L.: Bearing Strengths of 75S-T Aluminum-Alloy Sheet and Extruded Angle. NACA TN No. 974, 1945.

4. Moore, R. L., and Wescoat, C.: Bearing Strengths of 24S-T Aluminum Alloy Plate. NACA TN No. 981, 1945.

5. Anon.: Strength of Metal Aircraft Elements. ANC-5, Amendment No. 2, Aug. 1946.

6. Anon.: Alcoa Aluminum and Its Alloys. Aluminum Co. of Am., 1946, table 12.

TABLE I

TENSILE PROPERTIES OF 14S SHEET AND PLATE USED IN BEARING TESTS

[All values are average of two tests made in accordance with A.S.T.M. Standards (E8-42). W indicates with grain; X indicates across grain]

Alloy and temper	Sample	Nominal thickness (in.)	Direction of test	Tensile strength (psi)	Yield strength (offset = 0.2 percent) (psi)	Elongation in 2 in. (percent)
Alclad 14S-W	74466	0.064	X W	64,800 65,800	40,400 47,400	20.5 21.2
Alclad 14S-T	74467	.064	X W	68,200 68,800	60,700 62,000	9.5 11.0
Alclad 14S-W	74474	.250	X W	64,500 65,200	39,800 47,600	19.0 21.0
Alclad 14S-T	74475	.250	X W	68,000 69,600	59,700 63,800	10.2 11.5
14S-W	75933	.750	X W	66,500 69,600	43,900 48,300	16.0 17.3
14S-T	75958	.750	X W	70,600 71,600	62,800 63,800	8.3 9.8

TABLE II

COMPARISONS BETWEEN WITH-GRAIN AND CROSS-GRAIN STRENGTHS IN TENSION AND BEARING

Alloy and temper	Nominal thickness (in.)	Ratios of observed with-grain to cross-grain properties						Ratios of observed cross-grain to typical properties	
		Tensile ultimate	Tensile yield	Bearing ultimate		Bearing yield		Tensile ultimate	Tensile yield
				e = 1.5D[1]	e = 2D	e = 1.5D	e = 2D		
Alclad 14S-W	0.064	1.02	1.17	1.02	1.03	1.02	1.02	1.10	1.06
Alclad 14S-T	.064	1.01	1.02	.99	.93	.97	.93	1.05	1.05
Alclad 14S-W	.250	1.01	1.20	.97	1.02	1.00	1.04	1.09	1.05
Alclad 14S-T	.250	1.02	1.07	.97	.99	.97	.96	1.05	1.03
14S-W	.750	1.05	1.10	1.03	1.00	.97	.95	1.07	1.10
14S-T	.750	1.01	1.02	.96	1.00	.99	1.00	1.01	1.05
Average for W temper		1.03	1.16	1.01	1.02	1.00	1.00	1.09	1.07
Average for T temper		1.01	1.04	.97	.97	.98	.96	1.04	1.04

[1]e, edge distance; D, pin diameter.

TABLE III

BEARING STRENGTHS OF 14S SHEET AND PLATE

Alloy and temper	Specimen thickness (in.) (1)	Direction of test	Test	Bearing strengths (psi): Edge distance = 1.5 × pin diameter: Ultimate	Edge distance = 1.5 × pin diameter: Yield (2)	Edge distance = 1.5 × pin diameter: Type of failure (3)	Edge distance = 2 × pin diameter: Ultimate	Edge distance = 2 × pin diameter: Yield	Edge distance = 2 × pin diameter: Type of failure
Alclad 14S-W (74466)	0.064	X	1	104,100	66,000	S	131,300	78,000	S
			2	103,500	63,500	S	131,300	76,000	TS
			Av.	103,800	64,800		131,300	77,000	
Alclad 14S-W	.064	W	1	105,900	65,000	S	142,300	78,000	S
			2	105,900	66,900	S	129,400	79,000	S
			Av.	105,900	66,000		135,900	78,500	
Alclad 14S-T (74467)	.064	X	1	110,300	86,000	S	153,100	107,000	S
			2	109,800	85,500	S	141,100	102,300	S
			Av.	110,100	85,800		147,100	104,700	
Alclad 14S-T	.064	W	1	109,700	79,000	S	134,700	97,200	S
			2	109,400	80,000	S	149,700	96,500	S
			Av.	109,600	79,500		142,200	96,900	
Alclad 14S-W (74474)	.250	X	1	100,800	64,500	TS	129,500	77,000	TS
			2	99,200	66,000	TS	129,600	77,500	TS
			Av.	100,000	65,300		129,600	77,300	
Alclad 14S-W	.250	W	1	95,600	65,500	TS	130,500	79,800	TS
			2	98,800	68,000	TS	129,500	81,000	S
			Av.	97,200	66,800		130,000	80,400	
Alclad 14S-T (74475)	.250	X	1	104,000	87,200	TS	140,000	100,000	TS
			2	104,200	87,000	TS	135,600	96,000	TS
			Av.	104,100	87,100		137,800	98,000	
Alclad 14S-T	.250	W	1	100,000	86,300	TS	134,900	94,000	TS
			2	102,000	86,200	TS	132,000	95,000	TS
			Av.	101,000	86,300		133,500	94,500	
14S-W (75933)	.250	X	1	98,600	69,100	TS	131,600	85,000	S
			2	96,000	68,200	TS	131,700	81,700	TS
			Av.	97,300	68,700		131,700	83,400	
14S-W	.250	W	1	100,600	71,100	TS	130,000	74,500	S
			2	99,000	66,800	TS	124,400	84,500	TS
			Av.	99,800	68,900		127,200	79,500	
14S-T (75958)	.250	X	1	103,200	84,000	TS	136,900	97,500	TS
			2	101,600	83,900	TS	145,000	103,800	TS
			Av.	102,400	84,000		141,000	100,700	
14S-T	.250	W	1	98,400	82,500	TS	138,000	102,100	TS
			2	99,400	86,200	TS	141,600	100,000	TS
			Av.	98,900	84,400		139,800	101,100	

[1]All bearing specimens were 2 in. wide. Those of 0.064-in. thickness were loaded on a $\frac{1}{4}$-in.-diameter steel pin; those of 0.250-in. thickness were loaded on a $\frac{1}{2}$-in.-diameter steel pin.

[2]Bearing yield strength corresponds to offset of 2 percent of pin diameter on bearing stress-hole elongation curves.

[3]S indicates shear above pin. TS indicates combination of shear above pin and tensile fracture through hole.

TABLE IV

RATIOS OF AVERAGE BEARING TO TENSILE STRENGTHS

[BS, bearing ultimate strength; BYS, bearing yield strength; TS, tensile ultimate strength; TYS, tensile yield strength]

Alloy and temper	Nominal thickness (in.)	Direction of test	Ratios for edge distances of -			
			1.5 × pin diameter		2 × pin diameter	
			BS/TS	BYS/TYS	BS/TS	BYS/TYS
Alclad 14S-W	0.064	X	1.60	1.60	2.02	1.91
		W	1.61	1.39	2.06	1.66
Alclad 14S-T	.064	X	1.61	1.41	2.16	1.72
		W	1.59	1.28	2.07	1.56
Alclad 14S-W	.250	X	1.55	1.64	2.01	1.94
		W	1.49	1.40	2.00	1.69
Alclad 14S-T	.250	X	1.53	1.46	2.02	1.64
		W	1.45	1.35	1.92	1.48
14S-W	.750	X	1.46	1.57	1.98	1.90
		W	1.44	1.43	1.83	1.65
14S-T	.750	X	1.45	1.34	2.00	1.60
		W	1.38	1.32	1.95	1.58

TABLE V

COMPARISON OF RATIOS OF BEARING TO TENSILE STRENGTHS FOR 14S WITH

RATIOS FOR OTHER HIGH-STRENGTH ALUMINUM-ALLOY SHEET AND PLATE

Alloy and temper	Nominal thickness (in.)	Direction of test	Ratios for edge distances of -			
			1.5 x pin diameter		2.0 x pin diameter	
			BS/TS	BYS/TYS	BS/TS	BYS/TYS
Alclad 14S-W	0.064	X	1.60	1.60	2.02	1.91
Alclad 14S-T	.064	X	1.61	1.41	2.16	1.72
24S-T	.064	X	1.46	1.57	1.90	1.89
75S-T	.064	X	1.62	1.54	2.05	1.74
Alclad 14S-W	.064	W	1.61	1.39	2.06	1.66
Alclad 14S-T	.064	W	1.59	1.28	2.07	1.56
24S-T	.064	W	1.52	1.41	1.98	1.64
Alclad 24S-T	.064	W	1.53	1.37	2.00	1.56
24S-RT	.064	W	1.45	1.40	1.83	1.54
24S-T81	.064	W	1.45	1.42	1.97	1.59
Alclad 24S-T81	.064	W	1.54	1.46	2.06	1.61
75S-T	.064	W	1.63	1.46	2.03	1.66
Alclad 14S-W	.250	X	1.55	1.64	2.01	1.94
Alclad 14S-T	.250	X	1.53	1.46	2.02	1.64
24S-T	.250	X	1.50	1.53	1.90	1.83
Alclad 14S-W	.250	W	1.49	1.40	2.00	1.69
Alclad 14S-T	.250	W	1.45	1.35	1.92	1.48
24S-T	.250	W	1.43	1.23	1.82	1.54
14S-W	.750	X	1.46	1.57	1.98	1.90
14S-T	.750	X	1.45	1.34	2.00	1.60
14S-W	.750	W	1.44	1.43	1.83	1.65
14S-T	.750	W	1.38	1.32	1.95	1.58
24S-T	2.00	X	1.58	1.56	1.97	1.80
24S-T	2.00	W	1.45	1.55	1.76	1.75

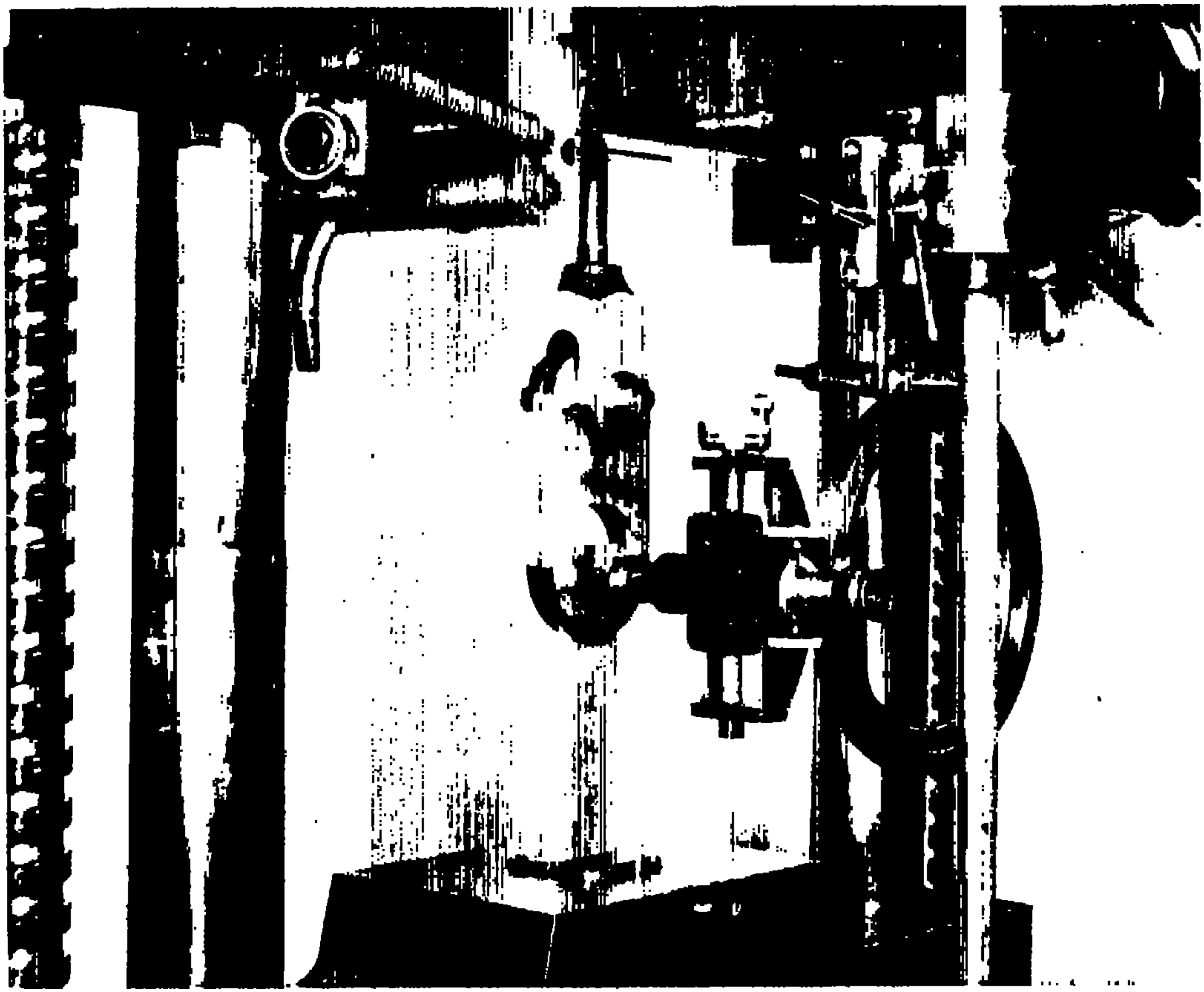

Figure 1.- Arrangement for bearing tests. Microscope used for measurement of hole elongations.

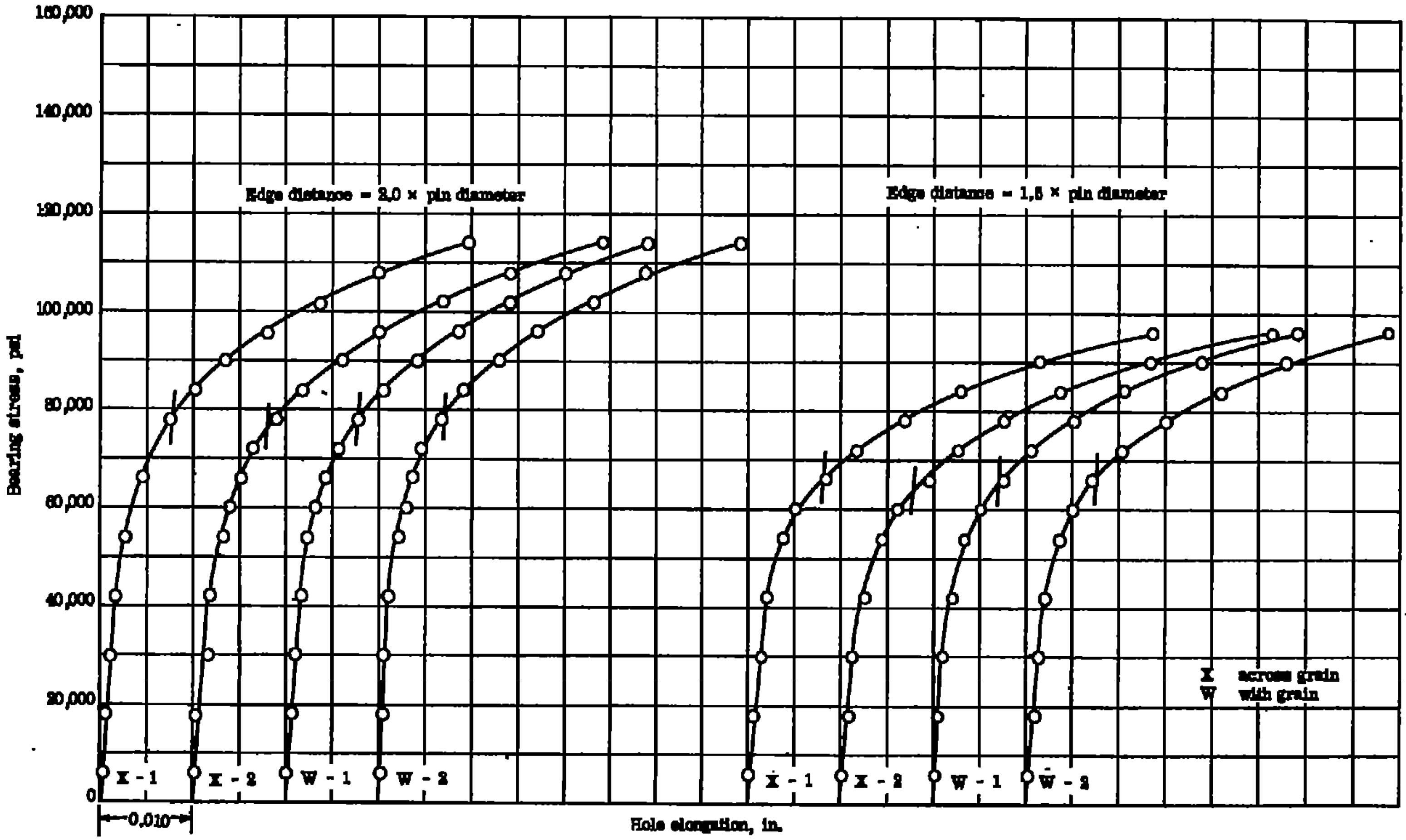

Figure 2.- Bearing stress-hole elongation curves for 0.064-inch-thick Alclad 14S-W sheet. Specimen thickness, 0.064 inch; specimen width, 2 inches; pin diameter, 0.250 inch; bearing-yield offset, 0.02 × pin diameter.

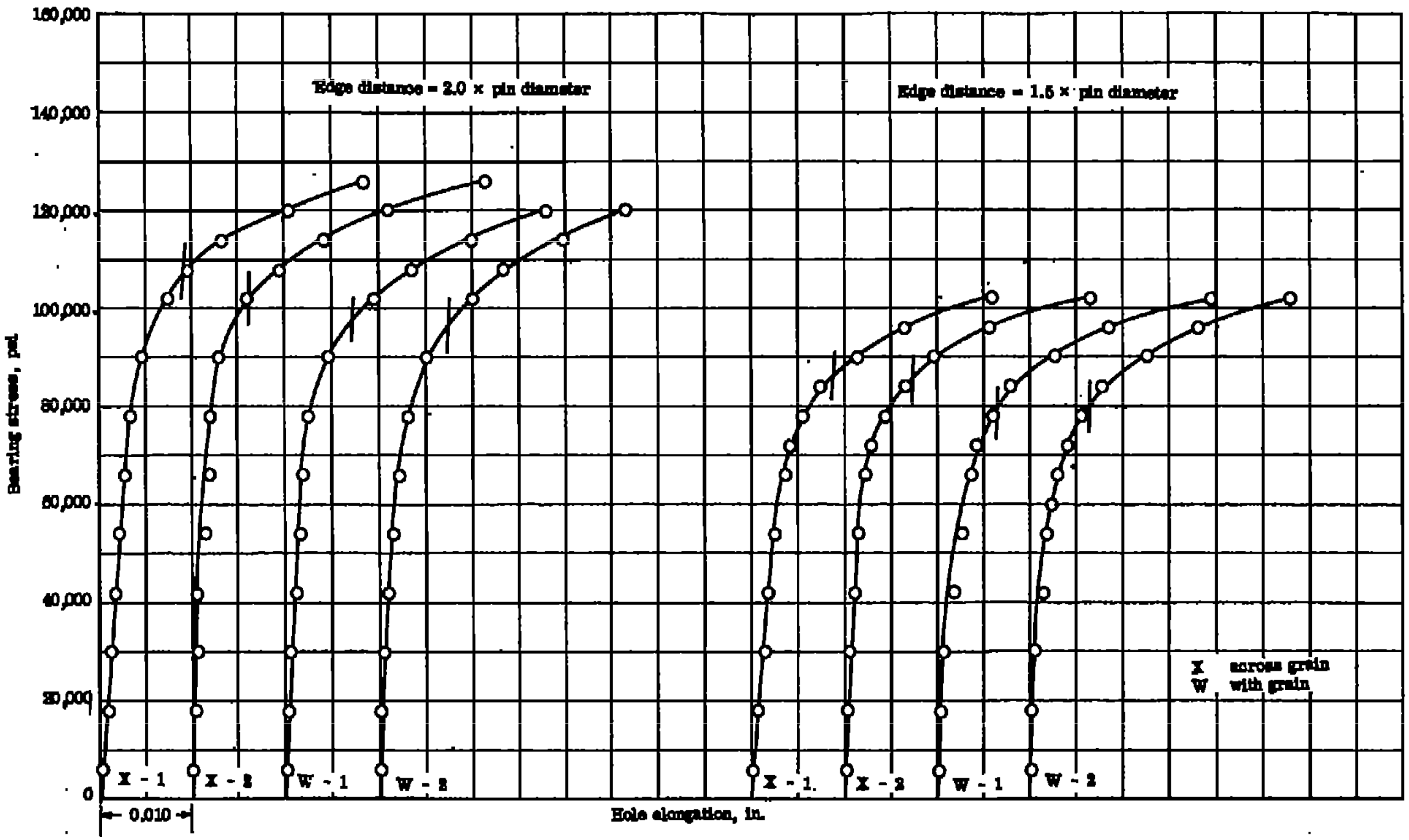

Figure 2.- Bearing stress-hole elongation curves for 0.064-inch-thick Alclad 14S-T sheet. Specimen thickness, 0.064 inch; specimen width, 2 inches; pin diameter, 0.250 inch; bearing-yield offset, 0.02 × pin diameter.

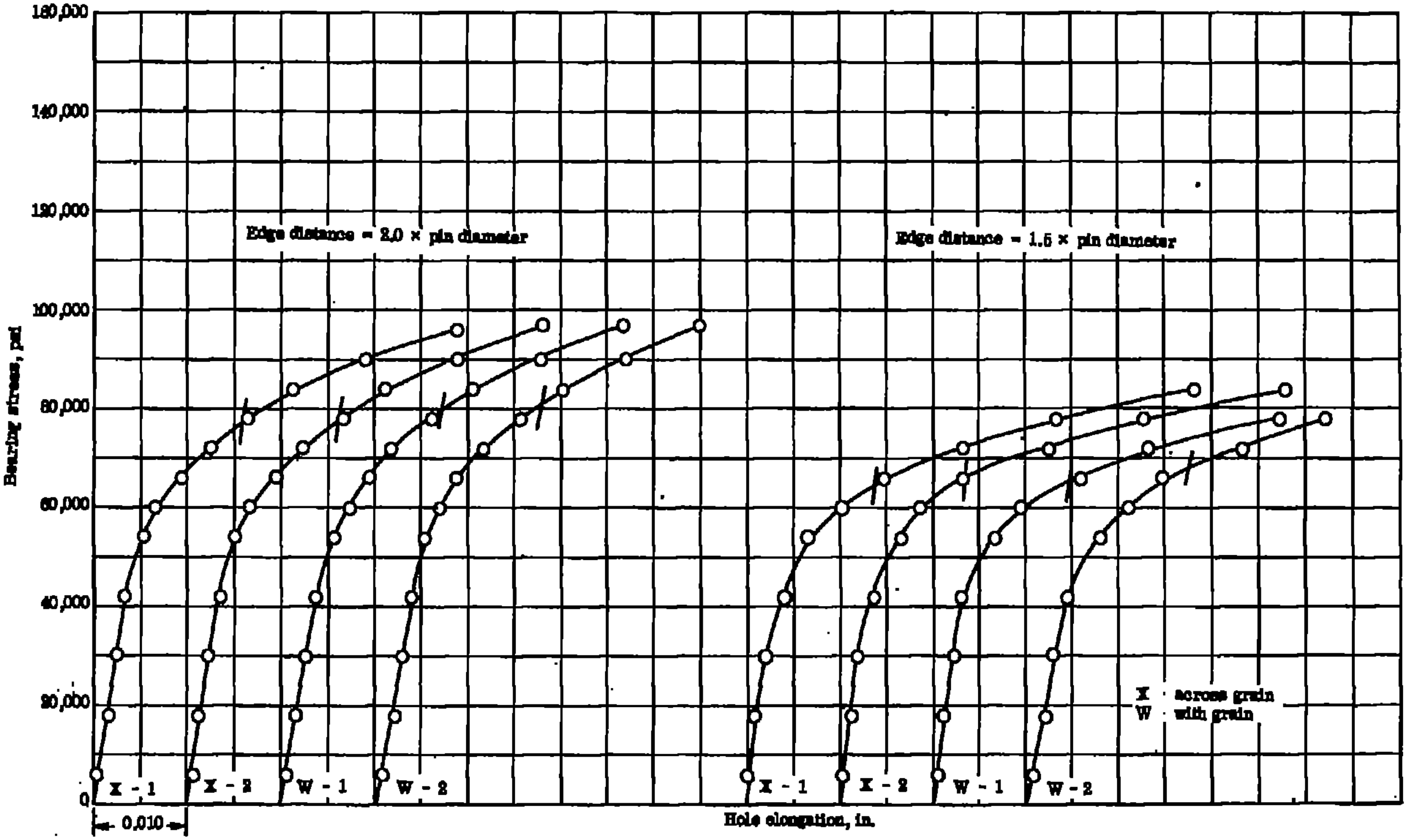

Figure 4.- Bearing stress-hole elongation curves for $\frac{1}{4}$-inch-thick Alclad 14S-W plate. Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

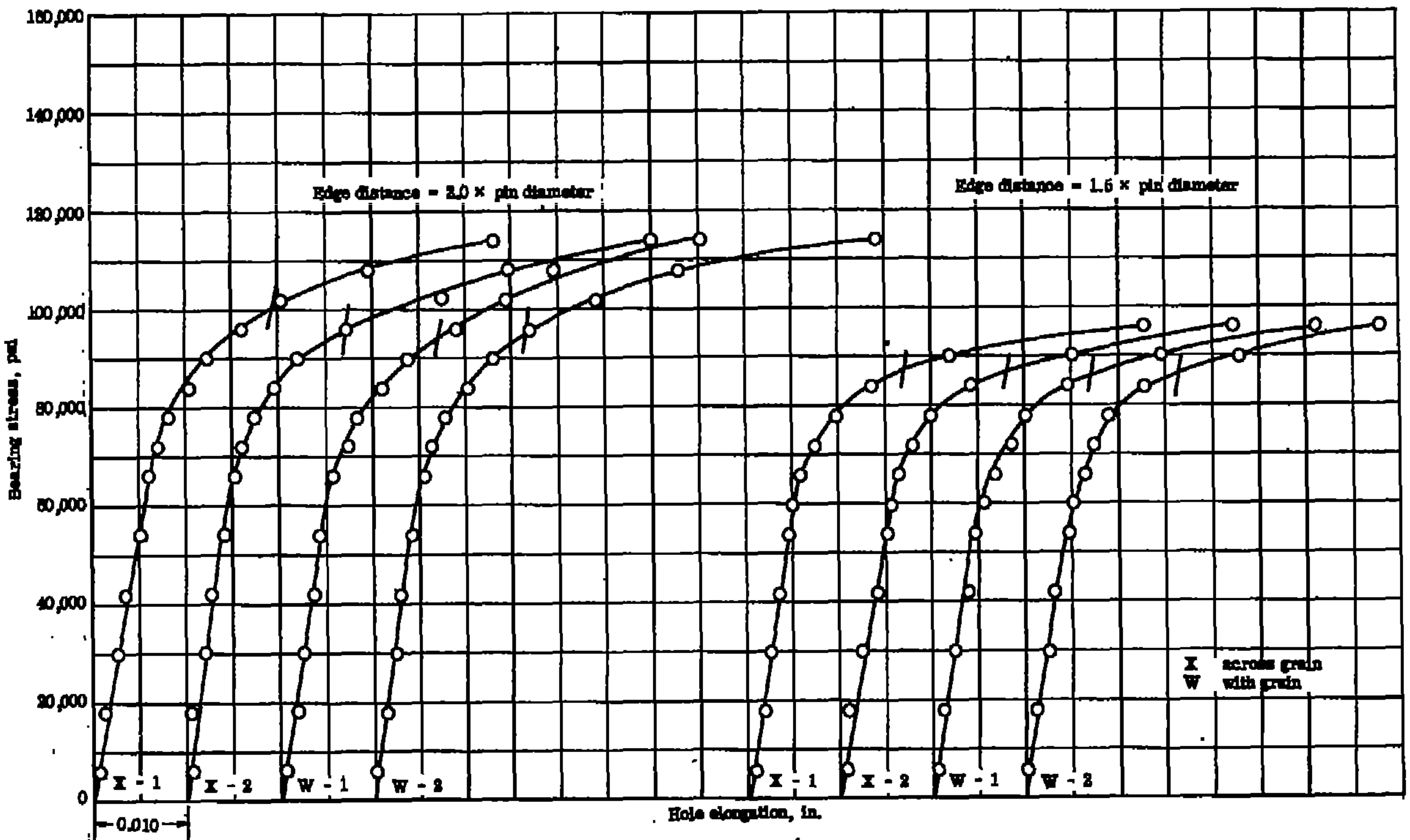

Figure 5.- Bearing stress-hole elongation curves for $\frac{1}{4}$-inch-thick Alclad 14S-T plate. Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

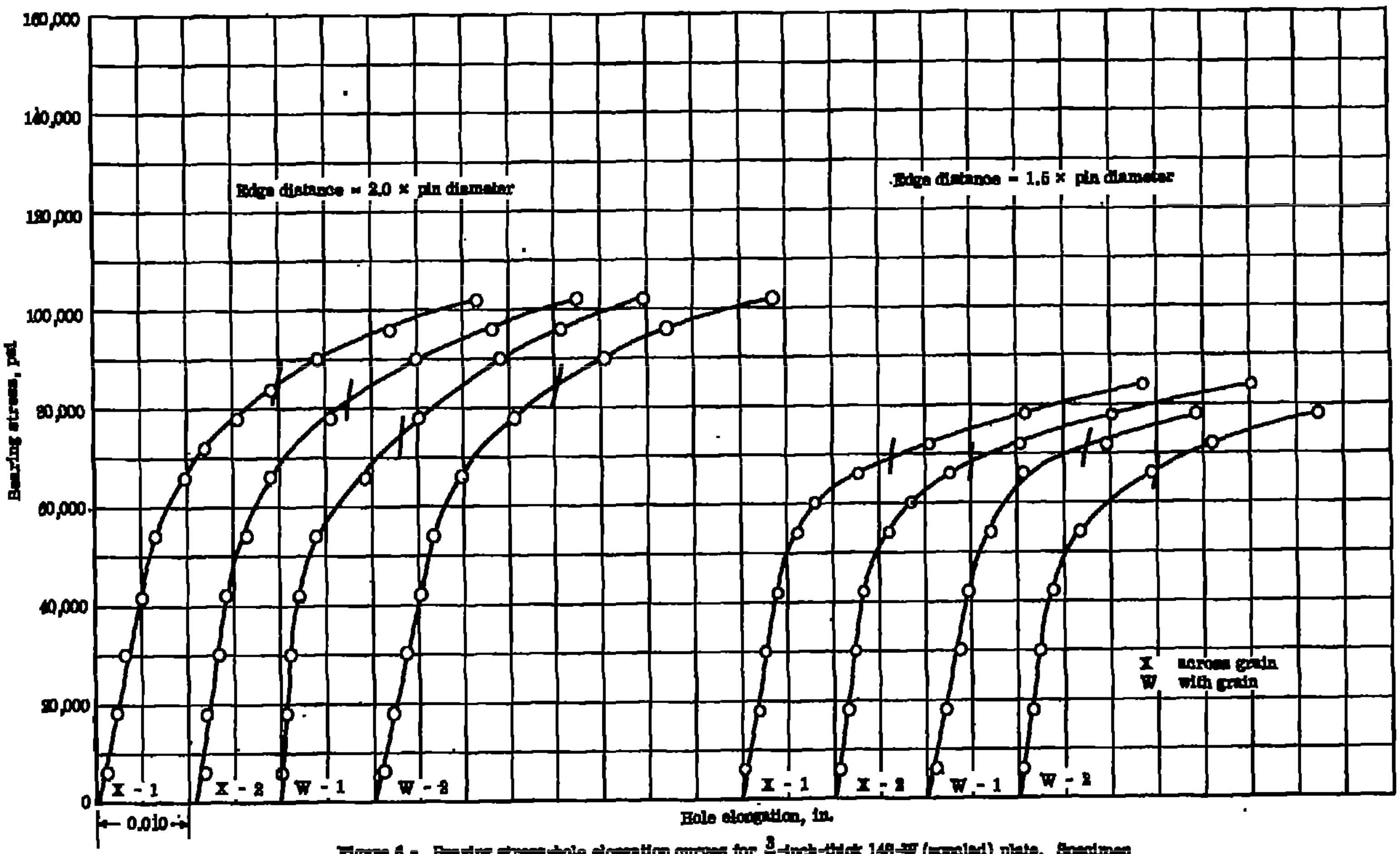

Figure 6.- Bearing stress-hole elongation curves for $\frac{3}{4}$-inch-thick 14S-W (unclad) plate. Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

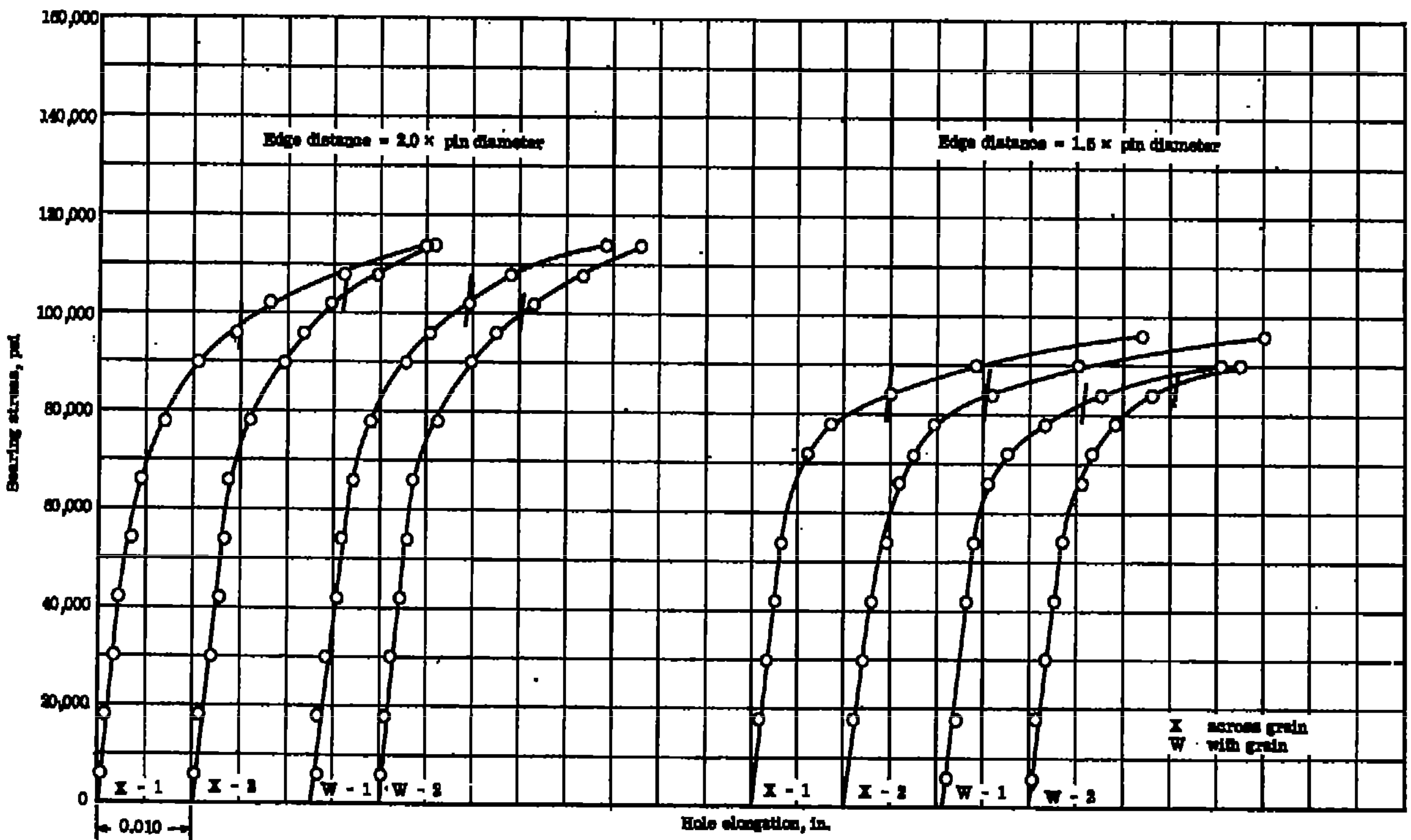

Figure 7.- Bearing stress-hole elongation curves for $\frac{3}{4}$-inch-thick 14S-T (nonclad) plate. Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.